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Cancer incidence among Norwegian airline cabin attendants

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Background Cabin crews are exposed to cosmic radiation at work and this may increase their incidence of radiation-induced cancers. Former studies indicate an increased risk of breast cancer.

Methods A retrospective cohort study was performed. The cohort was established from the files of the Civil Aviation Administration and included people with a valid licence as a cabin attendant between 1950 and 1994. The cohort was linked to the Cancer Registry of Norway. Observed number of cases was compared with expected, based on national rates. Breast cancer incidence was analysed, adjusting for individual fertility variables.

Results A group of 3693 cabin attendants were followed over 72 804 person-years. Among the women, 38 cases of breast cancer were observed (standardized incidence ratio (SIR) = 1.1, 95% CI : 0.8–1.5). Among men excess risks were found for cancers in the upper respiratory and gastric tract (SIR = 6.0, 95% CI : 2.7–11.4) and cancer of the liver (two cases, SIR = 10.8, 95% CI : 1.3–39.2). For both sexes elevated risks were found for malignant melanoma and non-melanoma skin cancer; for men these were SIR = 2.9 (95% CI : 1.1–6.4) and SIR = 9.9 (95% CI : 4.5–18.8) respectively, while for women these were SIR = 1.7 (95% CI : 1.0–2.7) and SIR = 2.9 (95% CI : 1.0–6.9) respectively. For no cancer site was a significant decreased risk found.

Conclusions An increased risk of radiation-induced cancers was not observed. The excess risks of some other cancers are more probably explained by factors related to lifestyle.

Keywords Cabin attendants, cancer, cosmic radiation

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In the working environment of airline cabin attendants, there are several exposures that might influence their cancer incidence: the introduction of jet aircraft with increasing cruising altitude has resulted in cabin crew being more exposed to cosmic radiation;[1] electrical equipment in planes produces low-frequency electromagnetic fields;[2] for decades cabin crew have been exposed to passive smoking at the workplace;[3] and cabin crew circadian rhythms are often disturbed by irregular working hours and, for some, travel through time zones.

Of these exposures cosmic radiation might be of importance. Ionizing radiation is known, or suspected, to be a cause of several types of cancer, at least for intermediate and high doses[4] and international recommendations regulate such exposure during work.[5] There is a discussion about how to check that exposure of pilots and cabin crew is within acceptable limits and how to impose regulations.[6,7]

There are few studies of cancer incidence among cabin attendants. In a cohort study of 1764 Finnish airline cabin attendants the incidence of various types of cancer was compared with that of the general population.[8] A major result was the excess risk of breast cancer among women. This was later supported by findings in a Danish study.[9]

Cabin attendants share their working environment with pilots and results from studies of this group may be informative.[10–14] These studies do not give a coherent picture of cancer risks among pilots, but they indicate that pilots have elevated risks of malignant melanoma and non-melanoma skin cancer.

The aim of this work was the study of cancer incidence among Norwegian cabin attendants, with an emphasis on cancer sites that have been discussed in relation to present workplace exposures and in former studies of aircraft crew.

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Material and Methods

The Civil Aviation Administration (CAA) authorizes cabin attendants in Norway. The cohort was established using information from the files at the Personnel Licensing Section and includes all those with a licence issued between January 1950 and February 1994. People of foreign nationality, who were not inhabitants of Norway for a reasonable time, were excluded. Before May 1983 cabin attendants had to renew their licence every second year and after that the licence was valid for a 5-year period.

The following information was extracted from the files at the Personnel Licensing Section: name, date of birth, company (if available) and date of renewals for licence.

Altogether, 3743 people were included in the cohort: 599 men and 3144 women. The files at the CAA do not include information on flying activities of the cabin attendants, so we used days of valid licence as a proxy for length of employment.

Since 1964 all inhabitants of Norway have a unique identification number. We searched these numbers for the cohort; 18 who had contact with the CAA after 1964 could not be identified and were excluded.

The date of death or emigration was found by linkage to the Population Registry of Norway using the identification number. It was revealed that seven had their first licence after emigration and they were excluded. For the period before 1965, the cohort was linked to the death registry by name and date of birth. People without identification number and no contact with the CAA after 1964, and who were not found in the death registry, were assumed to have emigrated at the last date of contact with the CAA.

The date of birth of live-born children among the women in the cohort was found by linkage to files at Statistics Norway. These files have been compiled using information from censuses and annual population statistics.

Since 1953 the Cancer Registry of Norway has collected data on incident cases of cancer in the total population. The registration system is built on multiple reporting from pathology laboratories and hospital departments, and there is compulsory reporting from physicians. The coding of cancers is based on a modified version of the International Classification of Diseases, 7th Revision (ICD-7).[15]

The cohort was linked to the Cancer Registry by the identification number or by the name and date of birth. The follow-up on cancer started on the date of first licence or 1 January 1953, whichever was later, and ended at emigration, death or 31 December 1996.

In the cohort, 25 people had emigrated before 1953, which left 3693 for the follow-up on cancer incidence.

The observed number of cases was compared to the expected number of cases and standardized incidence ratios (SIR) were computed by taking the ratio. The expected number of cases was computed by multiplying the person-years of follow-up by national rates in 5-year periods and 5-year age groups for each sex. The 95% CI of the SIR were computed by assuming that the observed number of cases followed the Poisson distribution. Observed versus expected ratios in different studies were compared by an exact binomial test.[16] Trends in the SIR were examined by categorization of the exposure variables. Trend tests were performed by assigning average scores to the categories.[16] Trends in SIR were tabulated for cancer sites or groups of sites with known or suspected association to exposures at the workplace. A multiple regression analysis of breast cancer incidence using several categorical and continous variables was performed. This analysis was restricted to women born after 1934 because only these have complete information on childbirth. The follow-up for this analysis started in 1964 because the linkage for fertility variables was based on the unique identification number. Rate ratios were computed adjusted for other variables in the model. Confidence intervals were based on profile likelihood methods. Trend tests for the exposure variables were performed by introducing numerical variables for the exposures.

The DATAB and AMFIT modules in the software package EPICURE were used in the analyses.[17]

Results

A cohort of 588 men and 3105 women was eligible for follow-up on cancer incidence. During follow-up, 61 men and 272 women emigrated, and 68 men and 55 women died. Expected deaths based on national mortality rates were 57.0 and 75.5, respectively. The number of person-years for men was 12 402, and 14.5% of these were after the age of 55 years. For women the number of person-years was 60 401, and 5.2% of these were after the age of 55 years.

During follow-up, 179 cases of cancer were observed, and the results for specific cancer sites are given in Table 1. For all sites combined, the SIR was 1.7 (95% CI : 1.3–2.2) for men and 1.1 (95% CI : 0.9–1.3) for women.

Among men there were significant excess risks of cancer of the upper respiratory and gastric tract and of liver cancer: 9 observed versus 1.5 expected and 2 observed versus 0.2, respectively. Both cases of liver cancer were hepatocellular carcinomas. The men also had excess risks of malignant melanoma: 6 observed versus 2.0 expected—and non-melanoma skin cancer: 9 observed versus 0.9 expected (basal cell carcinomas are not included). For these two cancer sites, there were also excess risks among women: 19 cases observed versus 11.2 expected for malignant melanoma, and 5 observed versus 1.7 expected for non-melanoma skin cancer. Among the women, there were 38 cases of breast cancer (SIR = 1.1; 95% CI : 0.8–1.5). For no cancer site was there a significantly decreased risk.

For *a priori* groups of cancer, the trends in SIR by length of employment are given in Table 2. With the exception of breast cancer, the figures are for both sexes combined as no differences in trend between sexes were found. The clearer trend seems to be for malignant melanoma, but even this was not significant at a 5% level.

Results from a regression analysis of breast cancer among the women are presented in Table 3. As a result of restrictions, this analysis included only 30 cases of breast cancer. The adjusted rate ratio for 15 years or more of employment versus less than 5 years of employment was 1.0 (95% CI : 0.3–3.0). There was no significant trend in incidence by length of employment. The adjusted rate ratio for no employment before 26 years old versus 3 years or more was 0.4 (95% CI : 0.1–1.9) but there was no significant trend in incidence for this exposure variable.

Table 1 Observed number of cases (O), expected number of cases (E) based on national rates, standardized incidence ratios (SIR) and 95% CI among cabin attendants in Norway

Cancer site[a]	Men				Women			
	O	E	SIR	95% CI	O	E	SIR	95% CI
All sites (140–204)	52	30.4	1.7	1.3–2.2	127	117.3	[illegible]	0.9–1.3
Upper respiratory and gastric tract (141, 143–148, 150, 161)	9	1.5	6.0	2.7–11.4	3	1.2	2.5	0.5–7.2
Stomach (151)	1	1.6	0.6	0.0–3.5	0	2.1	0.0	0.0–1.8
Colon (153)	2	2.4	0.8	0.1–3.0	6	6.3	1.0	0.4–2.1
Rectum (154)	1	1.6	0.6	0.0–3.5	6	3.0	2.0	0.7–[illegible]
Liver (155.0)	2	0.2	10.8	1.3–39.2	0	0.3	0.0	0.0–13.0
Pancreas (157)	1	0.8	1.2	0.0–6.7	0	1.3	0.0	[illegible]
Lung (162)	5	4.1	1.2	0.4–2.8	6	4.6	1.3	[illegible]
Breast (170)	0	0.0	0.0	0.0–81.3	38	34.0	1.1	[illegible]
Cervix uteri (171)					16	13.2	1.2	0.7–2.0
Corpus uteri (172)					3	5.5	0.5	[illegible]–1.6
Ovary (175)					6	7.8	0.8	0.3–1.7
Prostate (177)	3	3.7	0.8	0.2–2.4				
Testis (178)	2	1.3	1.5	0.2–5.5				
Kidney (180)	1	1.2	0.8	0.0–4.6	1	1.6	0.6	0.0–3.4
Bladder (181)	1	2.1	0.5	0.0–2.7	2	1.4	1.4	0.2–5.2
Malignant melanoma (190)	6	2.0	2.9	1.1–6.4	19	11.2	1.7	1.0–2.7
Non-melanoma skin (191)[b]	9	0.9	9.9	4.5–18.8	5	1.7	2.9	1.0–6.9
Brain, nervous system (193)	3	1.4	2.2	0.5–6.5	1	5.1	0.2	0.0–1.1
Thyroid (194)	0	0.3	0.0	0.0–14.5	3	4.1	0.7	0.2–2.1
Bone (196)	0	0.1	0.0	0.0–36.6	0	0.3	0.0	0.0–13.0
Soft tissue (197)	0	0.2	0.0	0.0–18.8	2	0.7	3.0	0.4–10.7
Hodgkin's disease (201)	0	0.4	0.0	0.0–9.7	0	1.1	0.0	0.0–[illegible]
Non-Hodgkin's lymphoma (200, 202)	4	1.2	3.4	0.9–8.8	4	3.1	1.3	[illegible]
Leukaemia (204)	1	0.7	1.4	0.0–7.8	1	1.6	0.6	[illegible]
Non-CLL (204)[c]	1	0.6	1.8	0.0–10.1	1	1.5	0.7	0.0–[illegible]
Multiple myeloma (203)	0	0.4	0.0	0.0–8.5	1	0.6	1.6	[illegible]–3.9
Unspecified (199)	1	1.0	1.0	0.0–5.7	2	2.1	0.9	0.1–[illegible]
Other sites (Rest 140–204)	0	1.2	0.0	0.0–3.0	2	3.2	0.6	0.1–2.3

[a] Codes of the *International Classification of Diseases*, 7th revision, in parenthesis.

[b] Basal cell carcinoma not included.

[c] Leukaemia excluding chronic lymphoid leukaemia.

Discussion

The incidence of breast cancer among Norwegian woman working as airline cabin attendants did not deviate significantly from that of the general population. There were 38 observed versus 34.0 expected cases. This is in contrast to the Finnish study in which there were 20 observed versus 10.7 expected cases.[8] Our study is three times larger than the Finnish study, but, as a result of the limited size of both studies, the two results are not significantly different. Combining results of the studies gives an SIR of 1.3. In the Finnish study, there were indications of increasing SIR by length of employment. This result is not corroborated by our study (Table 2). We did not find a trend by length of employment when adjusting for individual information about fertility variables (Table 3). The breast tissue is more susceptible to carcinogens at a young age and we included a variable for length of employment before the age of 26. This variable did not exhibit any trend in incidence (Table 3).

The cabin cohort indicated a steeper increase in breast cancer incidence by calendar time than actually observed in Norway in later decades.[18] However, we have to be aware that the estimated rate ratio for 'Before 1980' is based on only one case. For the cabin attendants we did not observe a lower breast cancer incidence among parous women compared to the nulliparous or a beneficial effect of early first birth as should be expected from results of a meta-analysis of Nordic studies.[19] Our analysis was based on only 30 cases and it should be noted that the expected trends by fertility variables are well inside the confidence bounds of our estimates. In a population-based study of young Norwegian women a time-related effect of births was demonstrated.[20] For a decade after births uniparous and biparous women had a higher breast cancer risk than nulliparous women. The cabin-attendant cohort is relatively young and they have their children later in life than the average population, so much of our observation of parous cabin crew will cover the initial period after births.

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Table 2 Trends in standardized incidence ratios (SIR) by duration of employment among cabin attendants for selected groups of cancer

Duration of employment (years)	Observed cases	SIR	95% CI	*P*-value trend test
Thyroid and non-CLL[a]				
<5	2	0.6	0.1–2.2	
5–14	2	0.8	0.1–3.0	
15+	1	1.3	0.0–7.4	0.52
Breast (women only)				
<5	19	1.2	0.7–1.9	
5–14	14	1.1	0.6–1.8	
15+	5	0.9	0.3–2.2	0.60
Brain and leukaemia				
<5	2	0.5	0.1–1.7	
5–14	3	1.0	0.2–2.8	
15+	1	0.8	0.0–4.3	0.62
Smoking-related cancers[b]				
<5	15	1.7	0.9–2.8	
5–14	8	1.3	0.6–2.6	
15+	6	1.2	0.5–2.7	0.53
Malignant melanoma				
<5	9	1.4	0.7–2.7	
5–14	9	1.8	0.8–3.4	
15+	7	3.6	1.4–7.3	0.07
Non-melanoma skin[c]				
<5	5	4.1	1.3–9.6	
5–14	5	5.9	1.9–13.8	
15+	4	7.4	2.0–19.0	0.38

[a] Leukaemia excluding chronic lymphoid leukaemia.

[b] Cancers of upper respiratory and gastric tract, pancreas, lung, kidney and bladder.

[c] Basal cell carcinoma not included.

Table 3 Adjusted rate ratios from Poisson regression of breast cancer among female cabin attendants born after 1934 by age, calendar period, number of children, age at first birth, length of employment and length of employment before 26 years old

Variables	No. of cases	Rate ratio	95% CI	*P*-value trend test
Age (years)				
<35	5	0.1	0.0–0.4	
35–39	2	0.1	0.0–0.4	
40–44	2	0.1	0.0–0.4	
45–49	13	1.0	Reference	
50–54	5	0.7	0.2–1.9	
55+	3	0.9	0.2–3.1	
Period				
Before 1980	1	0.2	0.0–1.2	
1981–1990	11	0.8	0.3–1.8	
1991–1996	18	1.0	Reference	
No. of children				
0	4	0.4	0.1–1.9	
1	7	1.3	0.4–4.2	
2	12	1.0	0.4–2.7	
3+	7	1.0	Reference	
Age at first birth (years)				
<25	6	1.0	Reference	
25–29	14	0.8	0.3–2.2	
30–34	5	0.7	0.2–2.5	
35+	1	0.5	0.0–3.3	
Length of employment (years)				>0.5
0–4	14	1.0	Reference	
5–14	11	1.1	0.4–2.6	
15+	5	1.0	0.3–3.0	
Length of employment before 26 years old				>0.5
0	2	0.4	0.1–1.9	
(0, 1)	4	1.4	0.4–4.5	
(1, 2)	4	0.9	0.2–2.8	
(2, 3)	11	1.2	0.5–3.0	
3+	9	1.0	Reference	

Supplementary analysis was performed to investigate potential confounding of the effect of the exposure variables. The exclusion of 'period', 'number of children' and 'age at first birth' from the model gave only small changes in the estimates for 'length of employment' and 'length of employment before 26 years'.

The concern about breast cancer among cabin attendants is motivated by the exposure to ionizing radiation. We do not have individual dose estimates for the cabin crew. Many of them have flown a mixture of long-haul and short-haul flights as previously reported for the pilots from the same companies.[14] Leukaemia, especially when excluding chronic lymphoid leukaemia (CLL), and thyroid cancer are other types of cancer that may be induced by ionizing radiation.[4] We did not observe excess risk of these types of cancer. Combining thyroid cancer and non-CLL, there was an apparent increasing trend by length of employment; this was far from significant because it was based on only five cases (Table 2). For the types of cancer most readily induced by ionizing radiation, we could not trace any effect of the exposure to cosmic radiation.

During work cabin attendants are exposed to low-frequency electromagnetic fields from the electrical equipment of the aircraft. The effect of this exposure on cancer incidence is unclear, with leukaemia and brain tumours being the types of cancer most often discussed in connection with this exposure.[21] The Norwegian cabin attendants experienced 6 cases of these cancers versus 8.8 expected, and these cases had no apparent trend with length of employment. Other studies of flying personnel have given conflicting results with regard to these types of cancer.[8,11–13] The limited size of all the studies and the lack of specific exposure estimates prohibit definitive conclusions.

The cabin attendants have, over the years, but probably less in later years, been exposed to environmental tobacco smoke (ETS). Without individual information about smoking habit, it is impossible to elucidate the influence of ETS on cancer incidence. Many cancer sites have been related to use of tobacco. In this study, we have defined cancers of the upper respiratory and gastric tract, pancreas, lung, kidney and bladder as tobacco-related. Among the women, there were 12 cases of tobacco-related cancers versus 10.2 expected, and among the men there were 17 observed versus 9.7 expected cases. The excess cases for men were found mainly in the upper respiratory and gastric tracts, a group of cancers that are also alcohol-related. An increasing trend by length of employment was not found in

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the SIR of tobacco-related cancers for either sex or both sexes combined (Table 2).

Among the men, we observed a significant elevated risk of cancers of the upper respiratory and gastric tracts, and for liver cancer. Use of alcoholic beverages is a risk factor for both these types of cancer. Excess risks of alcohol-related cancers have also been found in other occupational groups engaged in serving alcoholic beverages.[22]

Among both the men and women, elevated risks of malignant melanoma and non-melanoma skin cancer were observed. Excess cases of melanomas were also observed in the Finnish study[8] as well as in studies of pilots.[10–14] Among pilots, excess risks of non-melanoma skin cancer have also been reported.[10,12,14]

Solar radiation is a major risk factor for both these types of cancer.[23] Pilots are exposed to negligible doses of ultraviolet radiation in the cockpit,[24] and it seems unlikely that there is a higher exposure in the cabin. For both types of cancer, we compared the body distribution of cancer cases among the cabin attendants with that of the total population, and found no differences. For both types of cancer, an increasing trend in SIR by duration of employment was observed, although not significantly so (Table 2).

In Norway there has been an increasing trend in the incidence of these cancers, especially for malignant melanoma.[15] This has been attributed to changes in lifestyle and sunbathing habits. Increasing charter traffic to southern parts of Europe has been noted for decades. In the early days of this traffic it was not unusual for the crew of the aircraft to stay for some days at remote destinations. Employees at airline companies have had access to tickets at a reduced cost and may have taken the opportunity to travel to warmer and sunnier parts of the world.

For non-melanoma skin cancer, an excess risk was indicated after short length of employment (Table 2). Selective recruitment to the labour force of cabin attendants could be an explanation for this pattern.

Our study and those of others give cumulative evidence of excess risks of melanomas and non-melanoma skin cancers among aircraft crew, but it is difficult to point to workplace exposures as the cause. Our material does not allow investigation of a possible combined effect of the doses of c[illegible]nic radiation and exposure to ultraviolet radiation.[25] Individual details on both exposures and personal characteristics would be needed to do this in a proper way. The indications for exposure to solar radiation in leisure time remain the most possible explanation of the excess risks.

Our analysis of cancer incidence among cabin attendants was undertaken using information from the CAA. The CAA authorizes all cabin attendants serving aboard aircraft, thus ensuring a complete cohort. A shortcoming of the study is the lack of information about annual working hours and routes flown. This prohibits reliable estimation of doses of ionizing radiation and forced us to use 'days with valid licence' as a proxy for 'length of employment'.

Compared with other occupational groups, a large number of the cabin attendants emigrated during follow-up. This could imply a bias in the results if the reason for emigration was health-related. Most of the emigration occurred at a young age and we find it more probable that marriage to a foreigner or job opportunities were the major cause of emigration.

The population registries of Norway ensured a complete follow-up with respect to emigration and death, and provided us with individual information on fertility history. Use of the unique identification number facilitates and enhances quality of linkage to population registries and the Cancer Registry. Our study was three times larger than the Finnish study on cabin attendants but it is still a small study with limited ability to give reliable estimates of specific cancer risks. A clearer picture of cancer incidence might emerge in an extended follow-up with more person-years after the age of 55 years.

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Commentary: Cancer in the air

Elsebeth Lynge

Commercial air transport is a rapidly growing business and the work of aircrews entails occupational exposure to cosmic radiation mostly in the range of 2–4 mSv/year. In 1991, the International Commission on Radiological Protection recommended an occupational exposure limit of 20 mSv/year.[1] The actual exposure level of aircrews is thus normally well below the recommended limit. This limit is based, however, on disease occurrence in populations exposed to other types of ionizing radiation, e.g. following the Hiroshima and Nagasaki bombing. A detailed monitoring of the long-term health consequences of aircrew work is therefore well justified. The study by Haldorsen *et al.*[2] reported in this issue of the *International Journal of Epidemiology* forms part of the monitoring activity.

Epidemiological studies of mortality and cancer incidence in aircrews have recently been reviewed.[1,3] The studies fall into three categories. Firstly, proportional mortality, PMR, studies of military and commercial aircrews. Aircrew work requires health certification, and the group is subject to a strong healthy worker selection. The PMR studies may therefore be used only as a crude method of hypothesis generation. Secondly, cohort studies have been conducted of military pilots. Military pilots are, however, unlikely on average to receive the same cosmic radiation dose as commercial aircrews as they do not fly long hours in high altitudes. Thirdly, cohort studies have been conducted of commercial pilots and cabin attendants. These studies are clearly the most informative concerning long-term health effects of exposure to cosmic radiation. When it comes to assessment of the potential cancer risk, it is furthermore advantageous when these cohorts are followed for cancer incidence, as this implies more cases and more accurate diagnosis than the follow-up for cancer mortality.

At present, five cohort studies of cancer incidence in commercial air pilots have been published, two from Canada,[4,5] one from Denmark,[6] one from Iceland,[7] and one from Norway.[8] Two cohort studies of cabin attendants have been published from Finland[9] and from Iceland.[10] Data from one small cohort of retired cabin attendants from the US have been reported in letters,[11,12] and in a review.[3] Selected results from a small Danish cohort of cabin attendants have been published in a letter.[13] Haldorsen *et al.* in this issue of the journal report on a cohort study of Norwegian cabin attendants. Unfortunately,

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